SYSTEM AND METHOD FOR ASEPTIC FILLING OF PACKAGES WITH LIQUID PRODUCTS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of United States Provisional Application No.60/447,746, filed on February 19, 2003, the disclosure of which is expressly incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to aseptic filling of hollow packages with liquid products, particularly to aseptic filling of beverages in PET bottles.

BACKGROUND OF THE INVENTION

There is an increasing trend toward products that are highly sensitive to microbiological spoilage. These bio-sensitive products include ready-to-drink beverages, such as tea, coffee, and juice-containing ("health-image") drinks. Even water can be bio-sensitive, particularly if the water is still (i.e., un-carbonated) or has a high content of calcium/magnesium salts, which are the salts often regarded as healthy.

The filling process for highly bio-sensitive products must avoid virtually all traces of microbiological contamination within the closed package. For bottles and cans, this is currently achieved by 3 basic methods: hot-filling, post-filling pasteurisation and aseptic filling. In the case of hot-filling, the product is heated before filling and the package is filled with hot product, whereby the product temperature is sufficiently elevated so as to secure the sterility of both package and product, until the package is finally sealed. In the case of post-filling pasteurisation, the filled, sealed package is heated for a sufficient time to sterilise its content, normally in a tunnel pasteuriser. In the case of aseptic filling, the product, package and filling equipment are separately sterilised, and filling takes place at ambient temperature and in a sterile-maintained environment.

Aseptic filling does not require elevated temperatures, and therefore it is a more suitable process both for the products themselves and for heat-sensitive packages. Subjecting some products to high temperature for the time periods needed by hot-filling and post-filling pasteurisation, can affect product stability and cause taste deterioration (often giving a "cooked", "burnt", or "non-fresh" taste, usually faint but detectable). Additionally, some plastic packages set severe limitations to hot-filling and post-filling pasteurisation, because of the material's inherent temperature sensitivity.

Although many of the above advantages of aseptic filling apply to metal cans and glass bottles, they apply particularly to PET bottles, because of their high heat-sensitivity. For

example, PET bottles, suitable for hot handling, are not only expensive, but also cannot accept the high sterilising temperatures needed by some products (e.g., tea, coffee). However, the PET bottle is a convenient and attractive package, and can boost the marketability of bio-sensitive products. Therefore, lower-cost and more reliable aseptic filling methods can become an important marketing tool for such products.

In further detail, aseptic filling involves filling at ambient temperature, whilst ensuring that the microbiological content of the finally-packaged product is sufficiently low to ensure a sterile packaged product. Current methods for aseptic filling of beverage packages (cans or bottles) involve maintaining a sterile filling space. The sterile filling space is achieved either by maintaining the entire environment around the filler and capper machines under a sterile air blanket ("sterile room filling"), or else by maintaining a sterile air blanket around the critical machine sections and their associated ancillaries and conveyors. In principle, this means either maintaining a sterile environment around entire machines, or around the parts of machines where either product or unsealed package is open to its environment.

Maintaining a sterile filling space or a sterile room requires special equipment and operator training (far beyond normal standards in the industry), and involves product risk, because loss of the filling environment's sterility is neither quick nor easy to detect. Additionally, it is difficult to maintain sterility of non-product-contacting machine parts, especially the exterior of moving parts, such as shafts, motors, etc. Keeping a sterile filling space results in high cost due to the high cost of the equipment, the special conditions of the filling lines, and also due to the increase in transportation distance (because such specialised filling lines are necessarily few). Current aseptic methods do not permit the periodical switching to aseptic filling on conventional, non-aseptic filling lines, whereby this can be advantageous in certain cases, by securing better line utilisation and lower transportation distances.

Several attempts have been made to adapt the package itself, so that it can more easily be filled aseptically. In the pharmaceutical industry, the use of a membrane or "septum" is widespread, and such membranes have been used to avoid risk of microbiological re-contamination of the inside of a package during filling.

For example, Shaw (U.S. Patent Numbers 3,245,200; 3,382,642; 3,299,603; and 3,637,102) and Py (U.S. Published Patent Application Number 2002/0023409 A1) place a membrane over the container mouth and hold this down by some form of annular collar, leaving the membrane's top surface open. The membrane/container combination is then sterilised by external, non-invasive means (e.g., gamma irradiation), and punctured by a double-hollow needle for filling. Shaw then caps the collar to close its top annulus, leaving a gap between cap and perforated membrane. Py reseals the membrane by fusing the perforation, using lasers.

Emptying is by use of needles to extract the package's content through the membrane, which is suitable for doctor's surgeries, but not for normal consumers, who need simple, easy-to-use caps. The filling methods applied by Shaw and Py are special to their application, and only suitable for filling needles, not for the filling devices needed by high-speed equipment for consumer packages, such as beverage bottles and cans. Also, sterilising by gamma radiation would be difficult in a beverage plant, as well as questionable practice from standpoint of some consumer perceptions.

Membrane systems have also been applied to aseptic filling of flexible containers (i.e., bags). One example is Kruger (U.S. Patent Number 5,382,406), who focuses the filling of small bags for medicinal purposes. Further examples are Davis/Rica (U.S. Patent Numbers 4,445,550 and 4,494,363), Anderson (U.S. Patent Numbers 4,805,378 and 4,942,716 and European Patent Numbers 0 072 699; 0 236 107; and 0 271 242) and Lölliger (U.S. Patent Number 4,916,885), who focus the filling of bulk bags. In this set of applications, a membrane-containing spout is heat-sealed to bag's opening, the bag/membrane combination is then sterilised by external, non-invasive means (e.g., gamma radiation). A filling head, containing a filling tube, closes the open end of the spout, and sterilising vapour is used to sterilise the small space between membrane and filling head, after which the filling tube pierces the membrane and fills the bag (no venting provision is needed during filling, because this is a flat bag).

After filling, Kruger presses together the two sides of the bag in the area immediately beneath the spout to form a seam, which is heat-sealed. Davis/Rica heat-seal the top of the spout, using a lid, which was stored and sterilised within the filling head. Anderson and Lölliger heat-seal the base of the spout by including a hinged flap in the spout's base, which is pressed against the spout, through the bag wall, by the heat-sealer. In principle, all are directed toward the same result - one heat-seals the spout-top, the other the spout-base - so the membrane has no sealing (or re-sealing) role during the filling operation, but instead simply provides a means of pre-sterilising the package non-invasively.

Such bag-filling methods cannot be applied to rigid containers, however, and furthermore, they are not compatible with the filling devices needed by high-speed equipment for consumer packages, such as beverage bottles and cans. The closure, which results with all said methods, is really a portion of sealed bag and suitable only for special use, not for an easy-open consumer package. As already indicated, sterilising by irradiation would be difficult in a beverage plant, as well as questionable according to some consumers perceptions.

It is an object of this present invention to apply a membrane to the package as an integral part of a method, which can work with rigid (e.g., bottles, cans) or flexible packages, and can be applied to current high-speed package-filling technology, with minor modification, to enable

aseptic filling. It is a further object of this invention to enable the use of closures, which are not significantly different in cost or in consumer's ease-of-use to current closures. It is a further object of this invention to avoid sterilisation methods, such as gamma radiation, which are inappropriate in a beverage-filling environment and have negative consumer perceptions.

5

SUMMARY OF THE INVENTION

Accordingly, this invention involves a package adapted to facilitate aseptic filling methods, and methods and systems for filling aseptically that avoid the specialised machines and sterile-air-space requirements of current aseptic filling systems. The invention enables conventional non-aseptic filling equipment to be adapted relatively simply to fill aseptically. Since the need to fill under sterile air blankets is avoided, aseptic filling by the present invention can be by less specialized operators than would normally be required in aseptic filling operations. This has the general advantages of reduced equipment and filling costs and higher product security. It also has the advantage of enabling use of non-dedicated filling lines, which can then fill both non-aseptically as well as aseptically, each on a part-time basis, with change parts. This offers the possibility of reduced transportation distance (because it involves non-centralised filling and more dispersed filling lines), and increased line utilisation (because of greater line flexibility).

The invention can be applied to filling of all hollow packages, which have an opening, including cans and glass bottles, but has particular benefits in the filling of PET bottles, because these set severe temperature limitations. A further major advantage of the present invention is in the packaging of highly heat-sensitive products, which are also highly bio-sensitive, since the invention provides greater security against microbiological contamination.

The present invention may involve the use of a flexible membrane formed so that it can completely cover the package's mouth. The membrane may be formed so as to open and allow solid objects, such as machine parts, to pass or protrude through it, but additionally so as to re-close when the solid objects are removed. In a preferred embodiment of the membrane, the ability to allow solid objects to pass through it is achieved by petal-like segments, which fit closely together and spring back to re-seal against one another, when the solid objects are removed.

The membrane may be fitted onto the package's mouth prior to sterilising the bottle. The membrane may then be maintained in place throughout the sterilising, filling and capping stages, and the cap may finally be placed over the top of it. The membrane thus may become an insert within the cap, and may become attached to the cap. The membrane may serve in place of the cap's normal sealing compound, and may be removed together with the cap when a consumer opens the package.

Since sterilisation preferably takes place after the membrane is fitted to the mouth of the package, the membrane may trap the vapour of the sterilising medium within it and therefore maintain the package's internal sterility, even when the package is conveyed through the space of a normal (i.e., non-sterile) filling room. At the filler, a stream of sterile air (or inert gas) from

the filler bowl may displace the sterilising medium. On exiting from the package, the displaced sterilising medium may pass over the product-contacting parts of the filling valve, thus sterilising them before filling begins. After filling, the membrane may maintain a head-space of sterile air (or inert gas) within the package, whilst the package may be transported through a non-sterile space to the capper.

In summary, a membrane may allow the package to trap and maintain a sterile content, even when being transported in non-sterile spaces. Since prior to filling, the empty package may carry a sterilising medium, this not only keeps it sterile, but also provides a means of sterilising the filling valve's contact parts. After the filler, where the package may leave with product and with a sterile head-space, the sterile head space may be trapped and maintained by the membrane, even though the package is conveyed through non-sterile space to the capper.

The ability of the package to trap and maintain its internal sterility obviates the conventional need to maintain a sterile air environment over whole sections of machinery, and simplifies the process both from the equipment and the process control standpoints. This is because maintaining a sterile air environment over machine parts, as required by conventional systems, results in high cost and the need of special operator skills. The above-described method and principles fulfil the objects of the present invention by avoiding the complications, cost and operator training required by conventional aseptic filling systems, because there is no longer a need to maintain a sterile air blanket over machinery, since each bottle can carry its internal sterility with it through all the filling stages. Furthermore, because only relatively simple adaptation of conventional filling equipment is involved, the method can be applied on a part-time basis to lines which also fill non-aseptically, thus potentially enabling shorter transportation distances and higher line utilisation.

In one aspect, the invention includes a package comprising a filling aperture and an aperture-closing device, wherein the aperture-closing device opens to provide an opening that is greater than about 10% of the area of the aperture, and closes to provide a substantial barrier against contamination from outside the package and said device reseals after being mechanically opened. In one embodiment, the sealing provided by the device is sufficient to substantially trap a vapour content of the package. In another embodiment, the aperture-closing device is a flexible membrane. In another embodiment, the membrane is an elastomer selected from the group consisting of silicone rubber, natural rubber, butadiene, nitrile, sulphonic, isoprene, polyurethane, and viton. In another embodiment, the flexible membrane comprises flexible segments. In another embodiment, the flexible membrane achieves its opening and re-closing function through its elasticity, shape, or a combination thereof. In another embodiment, the aperture-closing device comprises a self-re-closing, hinged flap. In another embodiment, the

hinged flap substantially seals against an outer rim of the aperture-closing device. In another embodiment, the hinged flap substantially seals against an inner bore of the package aperture.

In another aspect, the invention includes a package comprising a filling aperture and a flexible membrane fitted over the filling aperture, the flexible membrane comprising flexible segments, wherein said flexible segments are adapted to permit passage of a sterilizing tube and a filling valve and to re-close with a sufficient seal to substantially trap a vapour content of the package when the sterilizing tube and filling valve are withdrawn. In one embodiment, the vapour trapped is a sterilizing vapour. In another embodiment, the flexible membrane is adapted to attach to a cap for the package. In another embodiment, the membrane opens to greater than 10% of the area of the filling aperture to accommodate the sterilizing tube and the filling valve. In another embodiment, the membrane is an elastomer selected from the group consisting of silicone rubber, natural rubber, butadiene, nitrile, sulphonic, isoprene, polyurethane, and viton. In another embodiment, the membrane replaces a sealing compound on the cap and the membrane is adapted to adhere to the cap. In another embodiment, the flexible segments have edges that are adapted to fit together or to overlap. In another embodiment, the package is a plastic bottle. In another embodiment, the package is a PET bottle. In another embodiment, the package is a metal or plastic can. In another embodiment, the package is a glass bottle. In another embodiment, the membrane is constructed of multiple materials. In another embodiment, the package is a flexible material and the filling aperture is a rigid material. In another embodiment, the package is constructed of multiple materials, layered materials or coated materials. In another embodiment, the flexible segments are adapted to permit the membrane to open to greater than about 10% of the area of the filling aperture. In another embodiment, the flexible segments are adapted to permit the membrane to open to greater than about 50% of the area of the filling aperture. In another embodiment, the flexible segments are adapted to permit the membrane to open to greater than about 90% of the area of the filling aperture.

In yet another aspect, the invention includes a method for aseptically filling a package having an inside, a filling aperture, and a membrane fitted over the filling aperture, the method comprising the steps of: filling the inside of the package with a sterilizing vapour; holding the sterilizing vapour on the inside of the package for a sufficient amount of time to sterilize the inside of the package; removing a portion of the sterilizing vapour; filling the package with a product; capping the filling aperture of the package containing the product; wherein the membrane is in place over the filling aperture during all steps of the method. In one embodiment, the method further comprises the step of allowing a sufficient quantity of the sterilizing vapour to exit the package before filling the package with a product to avoid affecting

the quality of the product, wherein the sterilizing vapour exits the package and sterilizes a part of a filling device that comes into contact with the product. In another embodiment, the membrane material is an elastomer selected from the group consisting of silicone rubber, natural rubber, butadiene, nitrile, sulphonic, isoprene, polyurethane, and viton. In another embodiment, the membrane opens to greater than about 10% of the area of the filling aperture during the filling steps. In another embodiment, the method further comprises the step of displacing the sterilizing vapour with sterile air, wherein the sterile air forms a headspace of the capped package. In another embodiment, the method further comprises the step of displacing the sterilizing vapour with inert, sterile gas, wherein the inert sterile gas forms a headspace of the capped package. In another embodiment, the method further comprises the step of pressing the membrane segments tightly against inner walls of the package to accelerate displacement of the sterilizing vapour by eliminating the gap between membrane segments and the inside of the package. In another embodiment, the method further comprises the step of allowing the sterilizing vapour to exit from the package during the step of filling the package with sterilizing vapour, wherein the sterilizing vapour that exits the package sterilizes an external surface of the package. In another embodiment, the method further comprises the step of conveying the package between the filling steps and the capping step in a non-sterile atmosphere, wherein the inside of the package remains substantially free of microbiological contamination. In another embodiment, the method further comprises the step of wetting the membrane with a fluid, wherein the wetted membrane has an increased ability to prevent entry of contaminants. In another embodiment, the fluid contains a bactericide and a thickener to increase the viscosity of the fluid. In another embodiment, the method further comprises the step of heating the package, wherein the heating increases the internal pressure of the gas in the package, and enhances prevention of entry of contaminants into the package. In another embodiment, the method is performed using conventional non-aseptic filling equipment adapted to fill aseptically. In another embodiment, the non-aseptic filling equipment is used aseptically part time. In another embodiment, the method further comprises the step of sterilizing an outside surface of the membrane before the capping step. In another embodiment, the step of sterilizing an outside surface of the membrane is achieved with a sterilizing medium that has a sterilizing effect of limited duration. In another embodiment, the step of sterilizing an outside surface of the membrane is achieved with a sterilizing medium that does not affect the quality of the product in small amounts. In another embodiment, the method further comprises the step of rinsing the parts of the filling device that come in contact with the product to be filled with hot water after each filling step. In another embodiment, the method further comprises the step of sterilizing the parts of the filing device that come in contact with

the product to be filled between filling operations by spraying with chlorinated water, by ultraviolet light, by enclosing in sterilizing vapour, or any combination thereof.

In still a further aspect, the invention includes a system for aseptically filling a package having a filling aperture, the system comprising: a membrane over the filling aperture of the package; a means for filling the inside of the package with sterilizing vapour; a means for holding the sterilizing vapour inside the package for a time sufficient to sterilize internal contact parts of the package and membrane; a filling device for filling the package with a product without removing the membrane; a means for removing a sufficient quantity of the sterilizing vapour from the package before filling the package with a product to avoid affecting the quality of the product, wherein the sterilizing vapour exits the package and sterilizes a part of a filling device that comes into contact with the product; a means for capping the package without removing the membrane. In one embodiment, the membrane is an elastomer selected from the group consisting of silicone rubber, natural rubber, butadiene, nitrile, sulphonic, isoprene, polyurethane, and viton. In another embodiment, a sprung insert replaces a conventional sealing material on the filling device and holds the membrane in place over the filling aperture during insertion of filling machine parts. In another embodiment, the membrane opens to greater than 10% of the area of the aperture. In another embodiment, the sprung insert provides a vapour seal in conjunction with the membrane. In another embodiment, the system further comprises conveyors to and from the filling device and the means for filling, wherein the conveyors are partly or wholly fitted with covers that contain sterilizing vapour to sterilize the outer surfaces of the package. In another embodiment, the sterilizing vapour is expelled through a snifft valve of the filling device.

DESCRIPTIONS OF THE DRAWINGS

FIGURE 1 is a representation of one embodiment of the membrane, both on its own and also fitted onto the finish of a bottle.

FIGURE 2 shows the operation of the membrane in conjunction with a filling valve.

FIGURE 3 shows a preferred embodiment of the aseptic filling method and system, using the membrane.

FIGURE 4 is a representation of a further embodiment of the membrane, both on its own and fitted onto the finish of a bottle, whereby the membrane's segments are inclined toward the inside of the package, so as to facilitate the passage of large machine parts.

FIGURE 5 is another representation of an embodiment of the membrane, both on its own and fitted onto the finish of a bottle, the membrane having no segments but being sufficiently flexible to open by stretching.

FIGURE 6 is a representation of yet another embodiment of the membrane, both on its own and fitted onto the finish of a bottle, the membrane having a flap that can be pushed open and that re-closes against the outer rim of the membrane.

FIGURE 7 is a representation of still another embodiment of the membrane, both on its own and fitted onto the finish of a bottle, the membrane having a flap that can be pushed open and that re-closes against the inner bore of the bottle's finish.

DETAILED DESCRIPTION OF THE INVENTION

While the figures and descriptions thereof below illustrate one embodiment of the invention in which bottles are the aseptically filled containers, it will be appreciated by those skilled in this art that the principles of the invention may be simply applied to cans and other containers with the same beneficial results.

Figure 1 shows one embodiment of the membrane. Membrane 1 may be made of a material of suitable flexibility and product compatibility, such as a suitable grade of silicone rubber. In fig. 1, membrane 1 may have an outer rim 2 and an inner section 3 comprised of a plurality of segments 4. Segments 4 may be divided by a plurality of lips 5. Lips 5 may be designed to fit together so as to be reasonably gas-tight. Membrane 1 may fit onto opening 6 of package 7.

In fig. 1, package 7 is shown as a bottle, but similar principles apply to cans and other hollow packages. A cap 8 may be placed on top of the membrane 1 after filling. Membrane 1 is preferably firmly attached to opening 6, so that membrane 1 may remain in correct position during the filling process described hereunder, until cap 8 is applied. There are several simple means of achieving adequate attachment between membrane 1 and opening 6. For example, membrane 1 can be shaped so that it grips the inner edge 9 of opening 6, as shown by fig. 1. Or, membrane 1 can grip the outer edge of opening 6 (not shown). Figure 4 shows a further example of firm attachment between membrane 1 and opening 6.

Figure 2 shows an embodiment of the invention in which membrane 1 operates within the filling valve 10 of a counter-pressure filling machine (not shown). Sprung insert 11 can replace the normal sealing rubber (not shown) of filling valve 10, which conventionally locates in recess 12 of the valve-bell 13. In the embodiment shown in Fig 2, sprung insert 11 consists of a collar 14, a spring 15 and a sprung face 16. The sprung face 16 may press down on membrane 1 so as to hold membrane 1 in place and prevent said membrane from moving, when the filler vent-tube 17 of filling valve 10 presses through membrane 1 and protrudes through it. Collar 14 may press membrane 1 away from filler vent-tube 17, thus creating aperture 18. The liquid product (not shown) can enter package 7 by means of aperture 18.

Figure 3 represents the principles and process steps of an embodiment of the present invention in relation to a filling line 21. At step A, membrane 1 is fitted into the opening 6 of package 7. Step A may involve a machine (not shown), which picks membrane 1 and places membrane 1 onto opening 6, preferably using state-of-art pick-and-place technology. When package 7 is supplied to filling line 21 from an outside source, conventional practice is to rinse said package immediately after feeding said package to filling line 21. In such a case, step A

may take place immediately after the conventional rinsing machine (not shown). Alternatively, if the filling line 21 is preceded by a bottle-blowing machine, or other conventional in-line package-making equipment (not shown), step A takes place immediately after said bottle-blowing, or other package-making equipment. Therefore, prior to step A, package 7 is physically clean, but micro-biologically non-sterile.

Package 7 may be conveyed from step A to subsequent steps B through G by means of conventional conveyors (not shown), which filling line 21 would normally have when filling non-aseptically. For the purposes of the present invention, the conveyor section between step A and step D is preferably enclosed by cover 22, at least part of the distance between the said steps. Package 7 may pass inside cover 22 when package 7 is being conveyed through steps B and C. Preferably, cover 22 has inlet section 23 and outlet section 24. Said sections 23 and 24 have apertures, which preferably fit reasonably close to the passing profile of package 7 and are connected by venting conduit 25 to water-ring vacuum pump 26. Water-ring vacuum pump 26 is conventional and is supplied with water feed 27.

At step B, sterilising medium spray tube 30 and sterilising medium vent tube 31 may be inserted through membrane 1, so that both said tubes protrude into the interior of package 7. Sterilising medium 32 may be piped to sterilising medium spray tube 30. Sterilising medium 32 can be a vapour or a volatile liquid. In one preferred embodiment, sterilising medium 32 is a mixture of the vapour of a bactericide 33, such as hydrogen peroxide, and sterile air.

Figure 3 shows a typical system 34 for producing a mixture of vapour of bactericide 33 and sterile air 35, so as to provide sterilising medium 32. In system 34, as shown, non-sterile air 36 may be blown by fan 37 through air heater/cooler 38 (which sterilises the air) and into a spray tower 39. Bactericide 33 may be circulated by bactericide pump 40 to the top of spray tower 39, so that it flows down spray tower 39 and saturates sterile air 35 (which flows upwards and counter-currently) with a vapour of bactericide 33. Sterilising medium 32 may exit from spray tower 39, and flow under the pressure generated by fan 37. Sterilising medium 32 may be piped to the parts of the aseptic filling process that require it, as described herein. System 34 additionally provides a separate stream of sterile air 35, which is also piped to the appropriate parts of the aseptic filling process, as described herein.

There are several conventional processes for producing sterile air 35 and a sterilising medium 32. System 34 is given only as example, for better understanding of the principles of the present invention. Systems for producing sterile air 35 and sterilising medium 32 are well known to those skilled in the art.

In step B, the sterilising medium 32, which enters through spray tube 30, may displace any non-sterile air 20 that may be trapped inside package 7. As a result, a mixture of non-sterile

air 20 and sterilising medium 32 may emerge from package 7 through sterilising medium vent tube 31. The non-sterile air 20, which is expelled from package 7, may mix with sterilising medium 32 and become sterilised. The sterilising medium 32 may fill package 7 and sterilise the interior of package 7. When sterilising medium 32 emerges from sterilising medium vent tube 31, it may fill the internal space 40 of cover 22, so that the exterior of package 7 and membrane 1 is also sterilised. Sterilising the exterior of package 7 and membrane 1 is not always essential, but it is preferable because a sterile or nearly sterile package exterior helps prevent re-contamination of interior of package 7.

In step C, package 7 may be held full of sterilising medium 32 for the necessary time to secure complete sterility, while being conveyed to step D. UV lighting can augment and accelerate the sterilising process in step D. The surplus sterilising medium 32, which enters internal space 40, may be ducted away by venting conduit 25 to vacuum pump 26, where it may be mixed with water feed 27 and ejected to drain. Vacuum pump 26 may exert a light vacuum on inlet section 23 and outlet section 24, so that sterilising medium 32 cannot escape into the atmosphere.

Steps D and E are the filling steps. In step D, package 7 may be conveyed conventionally and placed under filling valve 10. Package 7 may then be raised conventionally, and the top of membrane 1 may be pressed against sprung insert 11. Filler vent-tube 17 may protrude through membrane 1 and sprung insert 11 may create aperture 18 (see above description of fig. 2).

In fig. 3, the well-known counter-pressure operating form of a conventional filling valve is shown, including a filler bowl 44, with filler bowl headspace 45 and filler bowl liquid product reservoir 46. Inside the filler bowl 44 may be vent-tube valve 47, liquid valve 48 and vapour lock 49 (usually in the form of a sieve). The typical assembly of filling valve 10 includes a snifft-valve 50. As would be appreciated by those skilled in the art, a "snifft-valve" is the common term of the component of a filling device, which provides equalization of in-package pressure after filling. In addition to the counter-pressure form of filling valve described above, there are may other forms of filling valve 10 in commercial practice, but the invention should not be understood to be limited to any particular form of filling valve. The intent of fig. 3 is only to show the basic elements and how these can be adapted to the aseptic filling method of the present invention.

Conventionally, filling valve 10 operates as follows. Once package 7 is in position under filling valve 10, vent-tube valve 47 may be opened. Since headspace 45 is under pressure, air may flow down the filler vent-tube 17 and pressurize the content space 51 of package 7. As soon as content space 51 has similar pressure to headspace 45, liquid valve 48 may open and liquid product 52 may flow past vapour lock 49 into package 7, while the air in content space 51 may

be displaced up the filler vent-tube into headspace 45. When liquid product 52 reaches level of tip of vent-tube 17, content space 51 can no longer vent normally, and is thus prevented from venting via the path of liquid product 52 by vapour lock 49. At that point, the passage of liquid product 52 into package 7 stops, because no further air from content space 51 can vent and therefore no further liquid can enter. Vent-tube valve 47 may now close. The pressure of the residual content space 51 may then be released by opening the snifft-valve 50. When snifft-valve 50 begins to release the internal pressure of package 7, liquid valve 48 may close due to the pressure difference created across it. When the internal pressure of package 7 has been fully released, package 7 may be removed from filling valve 10.

There are many variations of commercial filling systems, but the operation described covers the basic elements of a counter-pressure filler, which is one of the most common filling modes for cans and bottles. An aspect of the present invention may be understood as an adaptation of a non-aseptic filling apparatus, such as the apparatus described above, into an aseptic filling apparatus.

In one aspect, the present invention includes the above-described commercial filling valve and filling operation modified as follows. Firstly, as already indicated in the description of fig. 2, the conventional sealing rubber of filling valve 10 may be replaced by sprung insert 11, and filling valve 10 may be sealed against the top surface of membrane 1. Filler bowl headspace 45 may be supplied with sterile air 35, which may be brought to the required pressure by compressor 55. Alternatively, headspace 45 can be filled with an inert gas, such as nitrogen, from a pressurised gas supply (not shown), which can be beneficial when the liquid product 52 is sensitive to oxygen spoilage.

The above-described filling operation may be modified to meet the aseptic filling objective of the present invention as follows. When package 7 is placed in position under filling valve 10, snifft-valve 50 may open to allow the sterilising medium 32 to be displaced by sterile air 35 from headspace 45. Snifft-valve 50 may remain open until sterilising medium 32 has been completely displaced from package 7, since traces of sterilising medi um 32 could otherwise spoil liquid product 52. The exiting sterilising medium 32 contacts and sterilises the contact parts of filling valve 10 (i.e., the liquid paths, the gas paths/cavities and the outside of filler vent-tube 17), rendering the contact parts of filling valve 10 sterile, before filling begins.

As soon as sterilising medium 32 has been displaced out of package 7, snifft-valve 50 may close, and filling may proceed in the conventional mode, as already described. Step D shows the displacement of sterilising medium 32 while snifft-valve 52 is open. A snifft-valve cover 56 may be used to trap the exiting sterilising medium 32 and duct it to vacuum pump 26, in order to avoid its escape into the atmosphere.

Where package 7 can withstand external pressure, as for example in case of glass bottles, the complete displacement of sterilising medium 32 out of package 7 can be speeded up by use of the type of filling valve which is often used for beer filling (not shown). Such versions of the filling valve can initially exert a vacuum within package 7, and thus accelerate removal of sterilising medium 32. If package 7 is made of plastic or other flexible material, exerting a vacuum inside package 7 may not be practicable, but displacement of sterilising medium 32 can also be accelerated by an increased flow of sterile air 35 (or inert gas) down filler vent-tube 17, which can be achieved either by enlarging the flow-cross-section of filler vent-tube 17, or by increasing the pressure in headspace 45, or both. However, accelerated removal of sterilising medium 32 from package 7 at step D is preferably accompanied by measures to reduce or eliminate re-contamination of the contact parts of filling valve 10 between filling operations, as further described below. This is because the removal of sterilising medium 32 has the added function of sterilising contact parts of filling valve 10, and such sterilising generally requires significant time, where excessive contamination exists.

In order to speed up the sterilisation of filling valve 10 by means of exiting sterilising medium 32 in step D, it may be necessary in some cases to rinse the filling valve 10 and its filler vent-tube 17 with hot water after each filling operation, so as to remove traces of liquid product 52. Alternatively, a water rinse, which contains a bactericide, such as chlorine, can clean, sterilise and reduce tendency to re-contamination. In addition, it is preferable to provide a cover (not shown) for filling valve 10 as it returns from step E back to step D, and allow sterilising medium 32 to flow inside said cover, since this too will reduce or eliminate re-contamination of filling valve 10 between filling operations. As further option, re-contamination of filling valve 10 can be reduced by directing UV light onto the exposed parts of filling valve 10, during the movement of filling valve 10 between filling operations. The use of UV light is particularly effective, if filling valve 10 is rinsed with chlorine-containing water, as described herein.

Other means of reducing re-contamination of the contact parts of filling valve 10 include use of a base-closing ball-valve (not shown) in the base of the filler vent-tube 17, which closes when flow pressure ceases (i.e., when vent-tube valve 47 closes). This inhibits significant entry of non-sterile air into the valve between fill-cycles. Alternatively, steam may be used to clean/sterilise filling valve 10, as filling valve 10 returns to fill position in step D.

These measures can reduce re-contamination of exposed parts of filling valve 10 prior to re-sterilisation in step D. These additional measures involve standard equipment known to those skilled in the art, and are not described further.

As indicated above, it is preferable to remove significant traces of sterilising medium 32 from the inside of package 7 before filling begins. One area of slower removal of sterilising

medium 32 is the area defined by gap 19 between package 7 and segments 4 of membrane 1 (see fig. 2). Removal of sterilising medium 32 from gap 19 can be accelerated by greater flow turbulence, which can be achieved by greater gas flow down filler vent-tube 17, as already described above. Another means of accelerating the removal of sterilising medium 32 in gap 19 is by increasing the number of segments 4 in membrane 1, since this increases the flow turbulence around the segments and reduces the flow path for displacement of sterilising medium 32. A further means of accelerating the removal of sterilising medium 32 in gap 19 is to eliminate gap 19 completely by extending the part of collar 14, which presses against membrane 1, in order to create aperture 18. By extending collar 14, segments 4 of membrane 1 can be pressed tightly against the walls of package 1, so that gap 19 is virtually eliminated (thus providing the added advantage of creating a larger aperture 18 for filling). The part of collar 14 that presses segment 4 against the wall of package 7 is preferably be perforated to avoid creating an area of poor flow between segment 4 and collar 14.

In fig. 3, step E shows the filling operation, with liquid valve 48 open. At the end of filling, this being the end of step E, residual content space 51 in package 7 may be filled with sterile air 35 from headspace 45 (or inert gas, if this is used in place of sterile air).

After completion of filling in step E, package 7 may be conveyed conventionally to a capper (not shown). In step F, part of the conventional conveyor between filling and capping is preferably fitted with a pre-capper cover 60. During the passage of package 7 within pre-capper cover 60, sterilising medium 32 may be sprayed onto the top of membrane 1 by medium spray 61. End sections 62 and 63 fit the passing profile of package 7 closely and are ducted to vacuum pump 26, as already described in connection with cover 22. The pre-capper space 64 inside pre-capper cover 60 becomes filled with sterilising medium 32, and the outside of package 7 and membrane 1 may be re-sterilised. The end section 63 is preferably as close as possible to the capper head, to eliminate excessive re-contamination on entry to capper (not shown).

In step G, a conventional capper may cap package 7, and membrane 1 may become the sealing element of cap 8. A contact adhesive within cap 8 (or similar method) may be used to bond membrane 1 to the underside of cap 8. Alternatively, hot-melt adhesive can be applied to the top of membrane 1 immediately before capping, which can help by sterilising the top surface of membrane 1, as well as gluing it to cap 8. Except when using hot-melt glue, a spray of sterilising medium 32 may be applied immediately under the capper head (not shown), just before capping in order to ensure sterility of the top of membrane 1 before cap 8 is finally applied. Since some of sterilising medium 32 may be trapped between cap 8 and membrane 1, a less aggressive, beverage-compatible sterilising medium (sterilising medium 32a) is preferably used. For example, sterilising medium 32a can be lightly-chlorinated water, applied to the

membrane immediately after it emerges from end section 63 prior to capper, since chlorinated water has an enduring bactericidal effect.

In some cases, pre-capper cover 60 in step F can be entirely replaced by spraying a suitable sterilising medium 32a, such as chlorinated water, which maintains sterility in contact with a non-sterile atmosphere.

Figure 4 shows an alternative embodiment of membrane 1, here denoted as membrane 66. Membrane 66 may have a plurality of inwardly inclined segments 67 that facilitate the passage of bulky filling valve components (e.g., can or bottle filling valve components) through membrane 66. Fig. 4 also shows an alternative means of attachment of membrane 66 to opening 6. The top rim 68 of opening 6 may be rebated to provide an inner surface 69. This enables the placement of a locking ring 70, which may be part of membrane 66 and need not generally protrude beyond the outer surface 71 of opening 6. The attachment of membrane 1 or 66 in the general manner shown in fig. 4, where locking ring 70 either grips inner surface 69, or simply surface 71 (not shown), enables segments 67 to be folded back until said segments come in contact with top rim 68 during filling, which provides the largest possible filling aperture.

Figure 5 shows a further alternative embodiment of membrane 1, here denoted as membrane 75. Membrane 75 has no segments and stretches open the central lip 76, sufficiently to enable the passage of filler valve parts, due to the flexibility of the material used for membrane 75 and/or the shape of membrane 75. Membrane 75 can re-close by returning to its original form.

Figure 6 shows yet another alternative embodiment of membrane 1, here denoted as membrane 80. Membrane 80 incorporates a flap 81, which closes against membrane lip 82 and is flexibly hinged by flap hinge 83. Membrane 80 may have an annular rim 84, which may provide a seal against cap 8 and to which hinge 83 may be attached. Filler valve parts can protrude through membrane 80 by pushing open flap 81, and flap 81 can re-close by flexibly returning to its original position.

Figure 7 shows yet a further alternative embodiment of membrane 1, here denoted as membrane 85. Membrane 85 may include a rim 86, which may provide a seal against cap 8. An arm 87 may project from rim 86 to a suspended flap 88. Suspended flap 88 may provide a seal against the inner bore of opening 6 of package 7. Suspended flap 88 can be opened by being pushed aside by filler valve parts, and re-close by flexibly returning to its original position.

The segments 4 of membrane 1 and membrane 66, and the sealing lips of membranes 75, 80, and 85, preferably provide a barrier to microbiological ingress when said segments are closed. Depending on material used for membrane 1, the sealing of segments 4 of membrane 1 against entry of microbiological contaminants can be enhanced by any of several methods,

including forming lips 5 to provide an angular, wedge-like contact between them; forming segments 4 to be slightly oversized, especially in conjunction with wedge-like contact between lips 5. Spraying a fine mist of bactericidal fluid, such as lightly chlorinated water, on top of membrane 1 at critical parts of process (e.g., immediately after step C and step D/E), can wet and seal the edges of lips 5. Increasing the viscosity of the chlorinated water by adding food-safe thickeners, such as glycerine or gum can enhance the sealing effect of the fluid. Increasing slightly the gas pressure under membrane 1 by heating may also enhance the sealing of segments 4 of membrane 1 against entry of microbiological contaminants. Localised energy may be directed to the gas in package 7 after step C, and to the headspace above the liquid after steps D/E, for example using a laser or IR (thus increasing gas pressure in the mbar order). This will enhance tendency of downwardly inclined segments 4 (e.g., segments 67 in fig 4) to be pushed upwardly and seal against one another. It will also enhance tendency for gas to flow out of package 1, thus preventing inward contamination.

Material combinations, leading to a multi-layer structure for membrane 1, can be beneficial in certain applications, particularly packages with large openings 6 – for example material layers to give springiness combined with sealing ability (i.e., soft/giving surface). Normally, membrane 1 will be formed by moulding. Depending on material and moulding process, it may be preferable not to fully cut lips 5, instead leaving them joined by a thin bridging-section of material, to be broken by first use (i.e., first entry of a machine component). Since separating lips by rupture is likely to lead to ragged, poorly-sealing edges, such moulding-tool-dependent bridging should be such as to reduce the thickness of the bridging section as much as possible.

The material of membrane 1 (or membranes 66, 75, 80 and 85) depends on the particular embodiment of membrane chosen (e.g., Fig 1, or fig 4, or fig 5, or fig 6, or fig 7) and on the practical material properties set by the application of package 7. Elastomeric materials are suitable for all embodiments, but non-elastomers are possible for some embodiments, primarily as represented by fig 6.

The main elastomer properties, which affect the selection of elastomer, include elasticity (for adequate "spring-back"), hardness/softness (for adequate sealing), food contact acceptability (for food packaging), temperature tolerance (depending on type of end use), chemical resistance (depending on type of end use and sterilising medium used), method of production (which determines selection of either thermoplastic or thermosetting elastomers) and cost. For food contact, a correct grade of silicone rubber may be preferred. Depending on application and the properties demanded by the membrane design, other elastomers, such as natural rubber, or butadiene, or nitrile, or sulphonic, or isoprene, polyurethane, or viton may be selected.

For non-elastomers (e.g in conjunction with fig 6), the main selection properties are similar to those already listed for elastomers, with the exception of elasticity. For non-elastomers, a "spring-back" property is needed. Non-elastomers with hinging and spring-back properties include polyolefins.

The embodiment design of membrane 1 (or membranes 66, 75, 80 and 85) should be such as to enable a significant proportion of opening 6 of package 7 to be opened and to be substantially re-sealed after opening. Furthermore, membrane 1 (or membranes 66, 75, 80 and 85) should normally open and re-seal more than once, especially where chemical sterilisation is used prior to filling, since this form of sterilisation involves intrusion of chemical injection devices past the membrane. The membrane embodiment design is therefore different than those of the "septum", which is well-known in medical practice, because much bulkier devices (e.g. filling valves) must be allowed passage by membrane 1 (or membranes 66, 75, 80 and 85). This contrasts with septums, which need only permit the passage of relatively slim needles. For bottle filling, membrane 1 (or membranes 66, 75, 80 and 85) must normally allow the passage of machine parts, such as filler valves, which require an opening of at least 3mm diameter, but desirably over 6mm diameter, preferably over 12 mm diameter and most preferably more than 20mm diameter. For can filling, membrane 1 (or membranes 66, 75, 80 and 85) must desirably provide an opening of at least 20mm diameter, preferably 30mm diameter, most preferably over 40mm diameter.

The reason that the size of aperture, which membrane 1 (or membranes 66, 75, 80 and 85) must provide, is much greater than that provided by said well-known medical septums, is because commercial containers, such as beverage containers, must be filled at high rates in order to be economical. For example, filling rates of 5,000 packages/hour would normally be regarded as minimal and rates over 60,000 packages/hour are quite common. Additionally, low filling rates (e.g. around 5,000 per hour or less) are usually associated with large containers, where the amount of fluid filling is still very considerable. For example, 20 litre bag-in-box packages are sometimes filled at rates as low as 60 per hour, but this is still equivalent to 1200 litres per hour, far beyond the capacity of a medical septum or its needle. Small packages, such as beverage cans are commonly filled at over 120,000 per hour, equivalent to over 40,000 litres/hour.

The high rate of package filling also affects the size of opening needed by chemical sterilisation devices (or other sterilisation devices, which must pass through membrane 1, or membranes 66, 75, 80 and 85), because the sterilisation operation also involves high rates and large fluid volumes. For example, where the sterilising medium is hydrogen peroxide vapour, a relatively large sterilising medium tube 30 will be needed, probably at least 6mm diameter and

frequently more than 12mm. Additionally, a sterilising medium vent tube 31 may also be needed and this would have a similar diameter.

The preferred high rate of package filling thus requires filling apertures in the packages of the invention to be relatively wide, and likewise requires the membranes or other aperture closing devices not to significantly restrict the package's filling aperture and to be capable of accommodating the relatively wide filling valve components and sterilization tubes. The membranes and aperture closing devices should thus be capable of opening to a significant proportion of the area of the filling aperture. In one embodiment, the membrane or aperture closing devices open to greater than 10% of the area of the filling aperture. In other embodiments, the membrane or aperture closing devices open to greater than 20%, greater than 30%, greater than 40%, greater than 50%, greater than 60%, greater than 70%, and greater than 80% of the area of the filling aperture. In a preferred embodiment, the membrane or aperture closing devices open to greater than 90% of the area of the filling aperture.

Provided opening 6 is rigid, package 7, as in the present invention, includes both rigid and flexible packages, as well as the most common forms of consumer packaging (i.e., bottles, cans and bag-in-box). The materials of package 7, which can be used in conjunction with present invention, include plastics (e.g. PET, PEN, polyolefin, nylon, polycarbonate, etc.), glass and metal. Also included within scope of present invention are combinations of materials for package 7, such as plastic/resin-coatings on metal, or on plastic or on glass. The construction of package 7 from multi-layer plastics is also included, where PET provides an example, since PET can be layered to include inner layers, which enhance its barrier or other properties, and for example, barrier layers from polyamide or EVOH (polyvinyl alcohol) are commonly used. For non-rigid packaging, the packaging film used to construct package 7 can often have a multi-layer structure of several plastics, while a metal foil (e.g. aluminium foil) can also be included within that structure.

While the focus of the present invention is PET bottles, similar principles can apply to cans or to other hollow packages with capped openings. Similarly, while the principles are described in conjunction with counter-pressure filling, similar principles can be applied to other types of filler, including vacuum fillers and piston fillers. While the invention has been described in combination with embodiments thereof, many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, the invention is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims. All patent applications, patents, and other publications cited herein are incorporated by reference in their entirety.